

DESIGN IDEAS

Basic program linearizes thermistors

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You can reduce the nonlinearity of a negative-temperature-coefficient (NTC) thermistor (TH-1) by adding a series resistor (RS) and a parallel resistor (R). Fig 1 contains the resulting network, designated R_{EQ} . To define optimum values for the resistors, the Basic program of Listing 1 uses an iterative process, selecting from standard values in data statements 480 through 560.

Using a 3-point straight-line approach, the program can linearize any NTC thermistor. First, the program prompts you for the lowest and highest temperatures of interest and the corresponding thermistor resistance

(which you can find in the manufacturer's data sheet). Next, it calculates the exact mid-range temperature and prompts you for the resistance at that point as well. You divide each resistance value by 1k before entering it in the program.

In the example of Fig 1, thermistor TH-1 varies 127 to 2.64 k Ω over the temperature range of 20 to 130°C. Resistance change in the lower half of this range (20 to 75°C) is 9.3 times greater than that in the upper half. By comparison, the computer-selected network R_{EQ} varies only 1062 to 977 Ω over the same temperature range, but the change in each half of the range is nearly equal. (Note, however, that the network's linearity error increases as you widen the specified temperature range.)

Text continued on pg 222

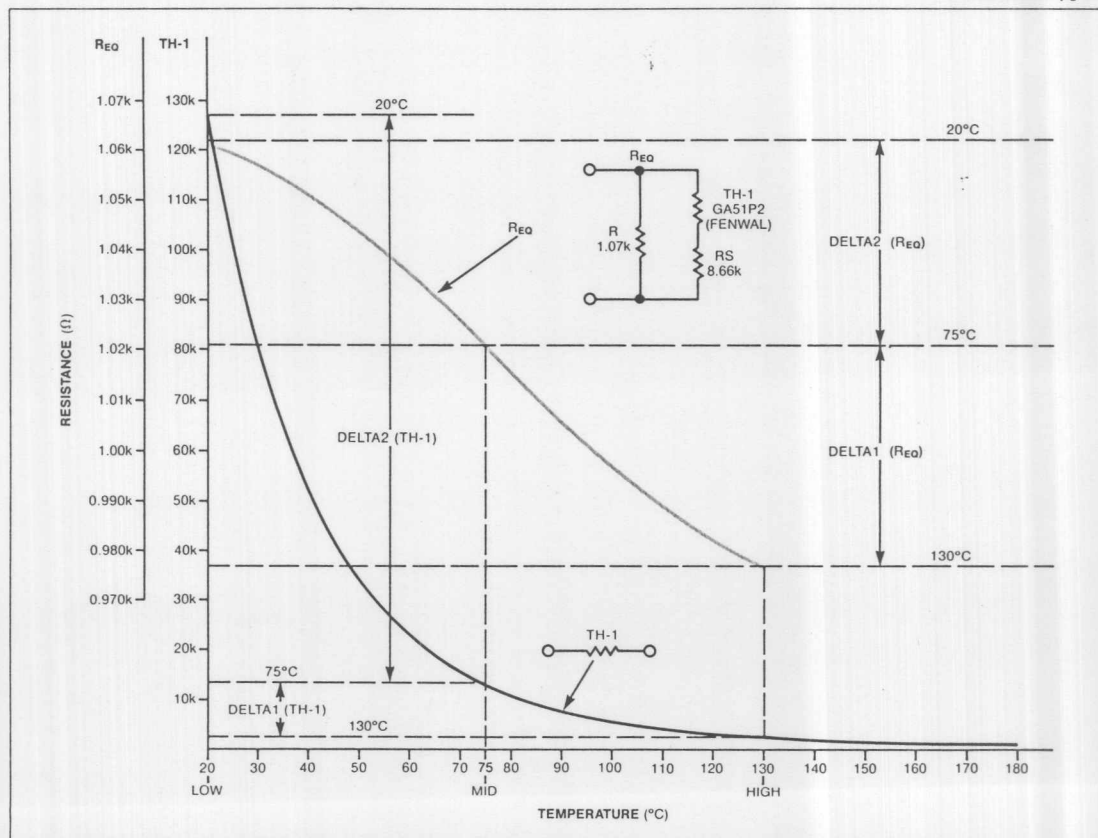


Fig 1—The Basic program in Listing 1 selects the standard values for resistors R and RS that provide the most nearly linear relationship between R_{EQ} and temperature.

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LISTING 1—LINEARIZATION PROGRAM

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10 REM *****
20 REM
30 REM THERMISTOR LINEARIZATION PROGRAM
40 REM COPYRIGHT 1986 MICK MURRAY
50 REM LAB-LINE INSTRUMENTS, INC.
60 REM MELROSE PARK, IL. 60160
70 REM
80 REM *****
90 A$=STRING$(70,"*")
100 FOR T=1 TO 24:PRINT:NEXT
110 INPUT"INPUT LOW TEMPERATURE:";L
120 INPUT"INPUT LOW TEMP RESISTANCE:";RL
130 INPUT"INPUT HIGH TEMPERATURE:";H
140 INPUT"INPUT HIGH TEMP RESISTANCE:";RH
150 M=((H-L)/2)+L
160 PRINT"THE CALCULATED MID-POINT TEMPERATURE = ";M;"DEGREES."
170 PRINT"INPUT THERMISTOR RESISTANCE AT ";M;" DEGREES:";
180 INPUT RM:ST=1000
190 REM DE=DELTA, ST=STORE
200 PRINT A$:PRINT:PRINT
210 DIM A(96):DIM B(96)
220 FOR X=1 TO 96:READ A(X):B(X)=A(X):NEXT X
230 FOR I=1 TO 96
240   FOR J=1 TO 96
250     LO=((RL+A(I))*B(J))/(RL+A(I)+B(J))
260     MI=((RM+A(I))*B(J))/(RM+A(I)+B(J))
270     HI=((RH+A(I))*B(J))/(RH+A(I)+B(J))
280     X=ABS(HI-MI)
290     X1=ABS(MI-LO)
300     DE=ABS(X1-X)
310     IF DE<=ST THEN ST = DE:RS=A(I):R=B(J):GOSUB 380
320   NEXT J
330 NEXT I
340 IF SD=0 THEN GOTO 580
350 PRINT" END OF CALCULATIONS."
360 PRINT CHR$(7);:FORP=1TO1000:NEXT:GOTO360
370 END
380 PRINT"BEST SO FAR:"
390 PRINT"RS =";A(I);"OHMS, AND R =";B(J);"OHMS."
400 PRINT" *** (AT";L;"DEGREES, Rth=";LO;"OHMS.)"
410 PRINT" *** (AT";M;"DEGREES, Rth=";MI;"OHMS.)"
420 PRINT" *** (AT";H;"DEGREES, Rth=";HI;"OHMS.)"
430 PRINT"DELTA1 =";X;"OHMS, AND DELTA2=";X1;"OHMS."
440 HL=ABS(HI-LO)
450 PRINT"THE TOTAL CHANGE IN RESISTANCE FROM";L;"TO";H;"DEGREES IS";HL;"OHMS."
460 PRINT:PRINT A$:PRINT"Working...":PRINT
470 RETURN
480 DATA 1.00,1.02,1.05,1.07,1.10,1.13,1.15,1.18,1.21,1.24
490 DATA 1.27,1.30,1.33,1.37,1.40,1.43,1.47,1.50,1.54,1.58
500 DATA 1.62,1.65,1.69,1.74,1.78,1.82,1.87,1.91,1.96,2.00
510 DATA 2.05,2.10,2.15,2.21,2.26,2.32,2.37,2.43,2.49,2.55
520 DATA 2.61,2.67,2.74,2.80,2.87,2.94,3.01,3.09,3.16,3.24,3.32
530 DATA 3.40,3.48,3.57,3.65,3.74,3.83,3.92,4.02,4.12,4.22,4.32,4.42
540 DATA 4.53,4.64,4.75,4.87,4.99,5.11,5.23,5.36,5.49,5.62,5.76,5.9
550 DATA 6.04,6.19,6.34,6.49,6.65,6.81,6.98,7.15,7.32,7.5,7.68,7.87
560 DATA 8.06,8.25,8.45,8.66,8.87,9.09,9.31,9.53,9.76
570 REM THE FOLLOWING IS FOR THE SECOND DECADE OF RS VALUES:
580 SD=1:RESTORE
590 FOR N=1 TO 96
600   READ A(N):B(N)=A(N):A(N)=10*A(N)
610 NEXT N:GOTO230

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(Fig 2). Remember to denormalize the final result by multiplying the resistance values by 1k. Typical execution time is about 10 minutes. **EDN**

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INPUT LOW TEMPERATURE: 20
INPUT LOW TEMP RESISTANCE: 127
INPUT HIGH TEMPERATURE: 130
INPUT HIGH TEMPERATURE RESISTANCE: 2.64
THE CALCULATED MID-POINT TEMPERATURE = 75 DEGREES.
INPUT THERMISTOR RESISTANCE AT 75 DEGREES: 12.96
*****
BEST SO FAR:
RS = 1 OHMS, AND R = 1 OHMS.
    *** (AT 20 DEGREES,  $R_{EQ}$  = .9922482 OHMS.)
    *** (AT 75 DEGREES,  $R_{EQ}$  = .9331552 OHMS.)
    *** (AT 130 DEGREES,  $R_{EQ}$  = .7844828 OHMS.)
DELTA1 = .1486723 OHMS, AND DELTA2= .059093 OHMS.
THE TOTAL CHANGE IN RESISTANCE FROM 20 TO 130 DEGREES IS .2077653 OHMS.
*****
                                :
                                :
                        (12 ITERATIONS)
                                :
                                :
*****
Working...
BEST SO FAR:
RS = 8.66 OHMS, AND R = 1.07 OHMS.
    *** (AT 20 DEGREES,  $R_{EQ}$  = 1.061627 OHMS.)
    *** (AT 75 DEGREES,  $R_{EQ}$  = 1.019542 OHMS.)
    *** (AT 130 DEGREES,  $R_{EQ}$  = .9774454 OHMS.)
DELTA1 = .0420962 OHMS, AND DELTA2= .04208481 OHMS.
THE TOTAL CHANGE IN RESISTANCE FROM 20 TO 130 DEGREES IS .08418102 OHMS.
*****
Working...
END OF CALCULATIONS.
```

Fig 2—This example of Listing 1's output shows two of the 14 iterations that the program prints in determining the R_{Eq} network in Fig 1. $R=1.07\text{ k}\Omega$ and $RS=8.66\text{ k}\Omega$ are the final values.

Circuit converts 7-segment code to decimal

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code, defined in Fig 2, can be active high or active low. In addition, for convenience sake you can substitute exclusive-NOR (XNOR) gates for the exclusive-OR (XOR) gates shown.

Table 1 shows the active-high output (P_i) that corresponds to each 7-segment character in the two sets, along with the intermediate BCD code (ABCD) that

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